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CLIMATE CHANGE IMPACT ADAPTATION AND MITIGATION IN FOREST SECTOR: THE CASE OF INDIA

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Abstract

Climate change, in particular increased temperatures and levels of atmospheric carbon dioxide as well as changes in precipitation and in the frequency and severity of extreme climatic events, is having notable impact on the world's forests and the forest sector. This paper deals with impact of climate change on forest sector. It outlines the anticipated climate change-related impacts, climate change policy strategies in forest sector and climate change adaptation options in forest sector. This paper concludes with some interesting findings along with policy suggestions.

Introduction

Climate changes directly and indirectly affect the growth and productivity of forests through changes in temperature, rainfall, weather, and other factors. In addition, elevated levels of carbon dioxide have an effect on plant growth. These changes influence complex forest ecosystems in many ways. Changes in average annual temperature, precipitation, length and timing of the growing seasons, and other climate-related factors can result in a number of both short- and long-term changes to forests, including altered growth rates, changes in stand structure and dynamics, and shifts in geographic distribution of both individual tree species and forest types. In addition to these direct effects, climate change has the potential to indirectly change the structure and dynamics of the entire forest ecosystem by affecting insect infestations, wildfire patterns, and other key processes and components of forested landscapes.

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Many aspects related to climate change are likely to affect forest growth and productivity. It could be observed in the form of increases in temperature, changes in precipitation, and increases in carbon dioxide (CO2). Warming temperatures generally increase the length of the growing season. It also shifts the geographic ranges of some tree species. Habitats of some types of trees are likely to move north or to higher altitudes. Other species will be at risk locally or regionally if conditions in their current geographic ranges are no longer suitable. It could be noted that species that currently exist only on mountaintops in some regions may die out as the climate warms since they cannot shift to a higher altitude.

Climate Change Impact on Forests

Climate change could alter the frequency and intensity of forest disturbances such as insect outbreaks, invasive species, wildfires, and storms. These disturbances can reduce forest productivity and change the distribution of tree species. In some cases, forests can recover from a disturbance. In other cases, existing species may shift their range or die out. In these cases, the new species of vegetation that colonize the area create a new type of forest. Hence, climate change adaptation in forest sector is very essential towards achieving sustainable development in forest sector. As per the report by IPCC (1996) it is important to keep in mind that a change in mean annual temperature as small as 1 °C over a sustained period is sufficient to bring about changes in species composition as well as distribution of many tree species. Under unavoidable and stable emission scenarios, forest productivity in currently temperature-limited or humid climates will stay constant or even increase as a result of CO2 fertilization. Under scenarios that assume that emissions remain stable or grow, forest productivity is expected to increase in northern biomes and decrease in the currently more productive southern forests due to the impact of pests and fire. The latter will produce high carbon emissions that will exacerbate climate change. Chaturvedi et al. (2010) Ravindranath et al. (2006) show that all forest types temperate to tropical are projected to experience an increase in net primary production between the 2030s and 2070s.

Under most scenarios, temperate forests are likely to be less affected than other forest types. Productivity is likely to increase in temperate forests closest to the poles and to decrease in temperate forests bordering the subtropics. Increasingly prevalent storms could cause major disturbances. Growth scenarios indicate that productivity in some subtropical woodland could increase due to the fertilizer effect of higher atmospheric CO2 levels but, in other cases, rising temperatures, higher evaporation and lower rainfall could result in lower productivity. Droughts will increase the prevalence of fire and predispose large areas of forest to pests and pathogens. In the subtropics the trend of increased fire is projected to wane in the latter part of the current century as lower rainfall reduces the availability of grass fuel. The subtropical domain contains many biodiversity hotspots that are at particular risk, even under stable or moderate climate scenarios. The productivity of tropical forests is projected to increase where sufficient water is available; in drier tropical areas, however, forests are projected to decline.

Anticipated Climate Change-Related Impacts

It is significant to note that climate change will have significant impact on forest throughout the world. It could be observed in the following ways losses in productivity are expected to occur in warmer and drier regions of the south, while modest gains are expected in the north, climate change will likely alter optimal growth conditions for tree species and local populations, changes will likely alter rotation age, wood quality, wood volume, and size of logs, wildfires and pest outbreaks will likely impact forests to a greater extent than the effects of changes in tree species and productivity, age distribution of forests is skewed towards older trees, making them more susceptible to pest and fire disturbances, increase in disturbance in younger forests will affect forest growth, species composition, and wildlife habitat and changes in fire regimes will likely affect the safety of people and property.

Impacts of climate change on forest tree species

Iverson et al. (2004), Dobrowski et al. (2013), Clark (2007), Corlett and Westcott (2013), predicted the impacts of climate change on forest tree species. They predicted the capacity of species movement and pointed out that species have historically moved much more slowly than future climate is projected to change. According to them humans may have a role in shifting species distributions and fragmentation or lack of suitable habitat can limit movement.

Aitken et al. (2008), predicted the Local adaptation of forest tree species and pointed out that many species have the capacity to adapt to changes in local conditions through refugia. Dobrowski et al. (2013), and Wang et al. (2012) pointed out the uncertainty in predicting future climate, particularly precipitation or aridity and water balance and aridity can be major factor in determining future tree growth. Zimmermann et al. (2009), predicted and incorporated effects of extreme events on tree species populations and pointed out that the extreme events in the form of frost, fire, flood, and high temperatures can be a major determinant of species survival. Thuiller et al. (2008), Kuparinen et al. (2010), and Kremer et al. (2012), reported the occurrence of lag effects and gene flow within species and species are generally still responding to past changes in climate and not optimally suited to current conditions. Brautigam et al. (2013), predicted the epigenetic effects of climate change on forest tree species in the form of the growing conditions of the parents can affect the capacity of progeny to cope with drier or warmer conditions. Anderson et al. (2012), and Brooker et al. (2007), noted the biotic effects of climate change on forest tree species reflected in the form of occurrence of insect pests and diseases and are the strong determinants of species distribution.

Nitschke and Innes (2008), predicted the phenology and life history traits of forest tree species in the form of age to sexual maturity, fecundity, seed dispersal, or chilling or dormancy requirements. Six (2009), and Gilman et al. (2012), predicted the climate change impact on tree species in the form of mutual benefits with plants or animals. It can be observed that some species have strong interactions with other plants, animals or micro-organisms that may respond differentially to climate. Castagneri and Motta (2010), predicted the competition effects of climate change impact on tree species. It can be observed in the form of open-grown conditions, competition with other tree species can determine species distribution.

Climate Change Impacts on Forests in India

Gopalakrishnan et al. (2011) made to projections based on a global dynamic vegetation model and pointed out the impacts of climate change on forests in India. The impact of climate change on forest sector can be observed in the following scenario

About 45 % of the forested area is likely to undergo change by 2035. The changes comprise an expansion of tropical evergreen forests in the eastern India plateau and the Western Ghats, slight expansion of forests into the western part of central India, and almost no change in vegetation type in the north-east.

Vulnerability assessments show that the vulnerable forest areas are spread across India, with a higher concentration in upper Himalayan stretches, parts of central India, the northern

Western Ghats and Eastern Ghats. North-eastern forests, the southern Western Ghats and the forested regions of eastern India are estimated to be the least vulnerable.

Temperate forests over 50 % of India's forest area are the most vulnerable. They are followed by tropical semi-evergreen forests and dry and moist deciduous forests. Climate change is not the primary cause of degradation of forests. Fragmentation and unplanned exploitation are main driving forces for the transformation of forests. Climate change aggravates the effects of these forces further. Ravindranath and Sathaye (2002) note that adaptation in the forest sector is crucial since local communities rely heavily on forests for their livelihood and since the impacts of climate change on forests, such as loss of biodiversity, are irreversible.

Ecosystem Approach in forest adaptation

An ecosystem approach should involve the following aspects: These include knowledge of the elements or components of the ecosystem and inter linkages or interdependencies among them; knowledge of the projected impacts of climate change and the vulnerability of the forest ecosystems and forest-dependent communities; emphasis on conservation, restoration, and sustainable use of forest resources through a participatory approach; identification of the factors contributing to forest degradation and loss as well as identification of measures to address these drivers that may impact the ecosystem services provided by forests, including biodiversity and carbon storage and sequestration; participation of all the stakeholders in developing and implementing adaptation and management practices — with special consideration of local communities; integration of local or traditional practices of adaptation to climate variability into adaptation plans and monitoring the changes in vegetation status and the impacts of the new adaptation or management practices implemented.

Adaptive Forest Management

Many challenges for adaptive management in general and adaptive management of forests, in particular, touch upon governance issues. These can be discussed here: distinguish impact of climate change from the impact of other pressures such as changes in land use; deal with risks that might come up in the future; take decisions despite little time or possibility of testing different options and assessing results from experiments: the climate may have already changed and experiments may no longer be valid; apply win-win, no-regret or low-regret measures instead of putting action on hold pending the availability of all desired information; improve the availability and quality of climate-related data; make sound economic cases for investing in adaptation; adapt institutions: make organizational culture, established structures and forest management policies more flexible and better prepared to quickly react to challenges not yet known before crises arise; move the responsibility for coordinating adaptation to powerful central bodies; apply an integrated cross-sectoral approach, in national development strategies and combine measures within and outside the forest sector and deal with the diverse, sometimes contradictory and competing, values and interests of the various stakeholders.

Climate Change Adaptation Policy Strategies in Forest Sector

Glück et al. (2009) proposed many climate change policy strategies in forest sector. These policy adaptation strategies are very essential in protection of forest resources in the context of climate change. The policy adaptation strategy on integrate forest issues into overall adaptation strategies has potential impacts. Such impacts could be seen in the form of allocating human and financial resources and reinforcing political importance and overall coordination. Enhancement in inter-sectoral coordination is the second climate adaptation strategy in forest sector. This adaptation strategy brings the potential impacts by the way of dealing with sectors that directly or indirectly, intentionally or unintentionally, influence decisions affecting forests, especially the agriculture and energy sector.

Implementation of national forest programme and the UN Forest Instrument of 2007 is the third climate adaptation strategy in forest sector. The impacts of the adaptation strategy aim at facilitating societal dialogue around forests and enhancing stakeholder participation, developing a comprehensive policy framework for all forest related initiatives and processes in a country and improving coordination. Enhancement in law enforcement and transparency is the fourth climate adaptation strategy in forest sector. The impacts of the adaptation strategy could be reflected in the form of implementing policies, combating illegal logging and increasing the sector's credibility.

Securing land tenure and developing fair and equitable cost and benefit sharing schemes is the fifth climate adaptation strategy in forest sector. The impact of the adaptation strategy could be observed in the form of engaging the private sector or communities and attracting investment. Empowerment of traditional and indigenous communities is the sixth climate adaptation strategy in forest sector. The impact of the adaptation strategy aims at applying traditional knowledge and benefiting from hands-on experience and observation and supporting adaptation of the generally most vulnerable parts of society. Applying ecosystem vulnerability assessments and ecosystem-based adaptation approaches is the sixth climate change adaptation strategy. This strategy has potential impact in the form of setting priorities for action, interacting with other sectors, and saving costs, since ecosystem approaches are often less cost-intensive and more likely to create win-win situations. Promoting economic valuation of forest ecosystem services is the seventh climate change adaptation strategy in forest sector. The impacts of the strategy aim at linking adaptation with mitigation measures. Applying monitoring and evaluation of adaptation measures is the eight climate change adaptation strategy in forest sector. The impacts of the strategy aim at recognizing trends and applying proactive adaptation. Supporting capacity development of institutions is the ninth climate change adaptation strategy forest sector. The impacts of the strategy aim at inviting new stakeholders to participate, enhancing flexibility within institutions and promoting network governance that gives room for innovative approaches.

Green India Mission

The Mission for a Green India puts ‘greening’ in the context of climate change adaptation and mitigation. It is meant to enhance: ecosystem services such as carbon sequestration and storage in forests and other ecosystems; hydrological services; biodiversity and adaptation of vulnerable species/ecosystems to the changing climate and other provisioning services such as fuel, fodder, small timber and non-timber forest products.

The concrete objectives of the Mission are to: increase forest/tree cover on five million hectares of forest/non-forest lands and improve quality of forest cover on another five million hectares a total of ten million hectares improve ecosystem services, including biodiversity, hydrological services and carbon sequestration as a result of treatment of 10 million hectares; increase the forest-based livelihood income of about three million households living in and around the forests and increase annual CO^2 sequestration by 50 to 60 million tonnes in the year 2020.

Climate change adaptation options in forest sector

Guariguata et al. (2008) and Booth et al. (2010) have identified several silvicultural practices for forestry to adapt to climate change. They include: adaptive management with suitable species and silvicultural practices; selection at the provenance level and selective breeding; changes to planting times, planting densities and general stand management; specific silvicultural options aim at facilitating genetic adaptation; and promotion of seed exchange and participatory genetic improvement programs across the industry.

Roberts et al. (2009), Galatowitscha et al. (2009), Canadell and Raupach (2008a), Ramakrishnan (2007)Ogden and Innes (2009), Hill, Baird et al. (1999), Raish, González-Cabán et al. (2005), (Cook 2003), Fung et al. (2002), Halpin (1997), Rebbeck et al. (2007), Innes et al. (2009), Kalame et al. (2009) and Booth et al. (2010), proposed a large number of adaptation options in conservation of forest resources in the context of climate change. These include promote agro forestry; offers direct benefits to landholders by diversifying production, improving resilience of land-use practices to environmental change, planting drought-resistant trees in areas expected to become drier, implement agro forestry practices on cultivated land; top prune trees to strengthen them against extreme wind events such as cyclones; use deep rooted species to tap moisture during drought conditions grow deep rooted perennials – potential to improve water-use efficiencies of vegetation, lower water tables, minimize erosion, improve soil carbon inputs, provide shelter and shade for stock longer harvesting cycles or reduced disturbance by the way of fires and insect outbreaks improved technologies to increase efficiency of water use, by the way of planting densities, nutrient adjustments use tree growth models and permanent sample plot records from existing plantations to plan alternative management strategies use of reduced impact logging to maintain ecosystem integrity, take climate change into account when planning establishment of new plantations, including giving greater weight to more recent climate data forest genetic research and tree-breeding programs species and cultivar choice – change in response to climate change, development of appropriate governance institutions to manage the transition to new sustainable development pathways' particularly in the tropics, and combat stressors and treats to forest such as habitat destruction, fragmentation and degradation afforestation in drought and arid areas with acacia spp.

As per the findings of many research studies the following climate change adaptation options are quite relevant. These include expanding reserves that lack adequate environmental heterogeneity, prioritizing protection of likely climate refuges, modifying restoration practices to rely on seeding and enlarge seed zones, threatened species abatement and recovery plans are an adaptation strategy that will benefit species, incorporate local forest-related knowledge in decision making and forest management, translation and linkage of local knowledge and formal forest science, and implement indigenous knowledge in fire management participatory research and linkage. Such options are should be taken in to consideration in planning for climate change adaptation in forest sector.

The climate change adaptation options such as develop migratory corridors or relieve other environmental pressures, corridor systems connecting reserves and stepping-stone reserves, afforestation or reforestation in the tropics i.e. provide more climate benefits reflection through increase cloud formation than similar land-change in boreal environments include common species from nearby southerly or drier locales is a logical low risk facilitation strategy, managing forests for multi-species and multi-aged stands, adaptive management requires ‘simultaneous implementation of alternative treatments, such as adaptive measures and policies, in different locations and comparison of results to test hypotheses about the behaviour of complex systems and policy and management recommendations aimed at integrating adaptation into national forest policies and practices and promote introduction of climate change adaptation into routine forest management could be taken into consideration while planning for climate change adaptation in forest sector.

The climate change forest adaptation options such as planting trees and harvesting products adapted to local climate conditions, fire prevention and management, including updating fire behavior, prediction systems for a changing fire regime tree borders/buffers to protect planted and native forests from weed invasion, including providing buffers for reserves to build resistance to drying climates, monitor populations at the edge as they are currently been exposed to conditions that will be the norm with climate change, monitoring “trailing edge” populations of rare species to support decision-making related to assisted colonization, use improved tools to assess risk of weed, pest disease problem under climate change while engaging with all levels of government use bioclimatic studies to identify key species in plantations and native forests, already under extreme climatic conditions, monitor these sites to provide early warning of potential problems, and improve regional level climate change modeling to provide more reliable scenarios to assist decision-making could be taken in consideration while planning for climate change adaptation forest sector.

Maintaining and Providing Ecosystem Services

Maintaining ecosystem services comprises maintaining the extent of forests. In this context, the adaptation options such as facilitating natural adaptation of biological diversity and maintaining forest health. Plantations play an important role in maintaining the extent of forests, enhancing forest cover and reducing pressure on existing forests. The choice of species within new plantations should take into account projected trends in climate change. It is also important to keep in mind that demand for fuel wood and timber will increase in the future. Possible measures to maintain the extent of forests may include: reducing deforestation and applying sustainable forest management practices in natural forests; using plantation species better adapted to future climate conditions than traditional ones; introducing anticipatory planting according to projected climate change at a given latitude and altitude; making use of plantations to supply an increasing demand for wood, but being aware of changes to groundwater levels caused by new plantations. The climate change forest adaptation options such as converting plantations to more natural forest types so as to enhance ecosystem services; integrating biofuel production into an overall concept in order to avoid conversion of forests; enhancing local welfare by promoting community-based forest management and restoration, developing agroforestry, making microfinance available, and promoting a greater role for women; offering training in management, manufacturing and marketing of non-timber forest products and supporting efforts to improve welfare through sound governance, strengthening institutions, greater participation and education, greater accountability, and reinforced monitoring and community access to benefits could be taken into account while planning for climate change adaptation in forest sector.

The climate change adaptation options in forest sector such as facilitating natural adaptation of biological diversity is crucial as it enhances the resilience of ecosystems. In this regard, many actions associated with sustainable forest management are considered. These include: employing landscape-level approaches to conserving biodiversity, enabling species to migrate to areas with more suitable climates; assisting migration of provenances and species; reducing fragmentation and maintaining connected areas of forest, especially links between protected areas; protecting primary and natural secondary forests; expanding reserve systems to ensure protection of genetically diverse populations and species-rich ecosystems; enhancing diminished ecosystem services or replacing lost ecosystem services and changing the species composition of forest stands and planting forests with genetically improved seedlings adapted to a new climate.

Proactive Climate Change Adaptation in Forest Sector

There is considerable evidence that climate change affects forest health and vitality and will continue to do so. Forest management may be able to reduce the impacts of events such as forest fires, pathogens or insect epidemics. The proactive adaptation depends on: increasing the genetic diversity of trees used in plantations; reducing the impact of climate change and major changes to a forest which may render it more susceptible to future events; applying management techniques such as thinning, prescribed burning and selective cutting to mitigate the threat of mega-fires and developing strategies for dealing with forest insects, pathogens, and invasive species and applying phytosanitary standards.

The following proactive measures are proposed to complement sustainable forest management and maintain provisioning services: undertaking landscape planning to minimize fire and insect damage by the way of introducing multi-species plantings and reducing logging waste; shifting to species or areas that are more productive under new climatic conditions; altering stand management within and between regions according to timber growth by the way of shortened or extended rotation periods and harvesting patterns in terms of reducing damage to remaining trees, and salvaging dead timber, adjusting to altered wood size and quality; adjusting fire-management systems; implementing soil conservation practices; evaluating local preferences carefully and assisting communities in choosing and applying options for tree and forest management and taking account of traditional knowledge and cultural and spiritual values.

Maintaining and Providing Regulatory Services

Maintaining and providing regulatory services means maintaining soil and water resources and enhancing forestry's contribution to global carbon cycles under conditions of climate change. Experienced foresters and local communities understand the protective functions forests can have. These are important to safeguard infrastructure and human life and are widely used in mountain areas. Forests also play an important role in watershed management; they can enhance the quality and quantity of soils and water. However, forests use more water than grasslands. Consequently, new plantations may cause changes to groundwater levels and reduce stream flows. It makes sense to combine mitigation and adaptation measures, since forests can only contribute to mitigation if they keep their adaptive capacity to climate change.

Research Needs for Climate Change Adaptation and Mitigation in Forests

To implement national climate change and forest policies, there is need for in-depth knowledge of appropriate methods and tools as well as awareness of available funding mechanisms, such as the carbon market and adaptation funds established under the IPCC. Extension services will need to be strengthened substantially in order to address adaptation and mitigation for them to provide an efficient interface between policymakers and the forest community. Recognizing that climate change will alter many existing equilibriums, socio-economic dynamics must be considered, and the role of all the partners may need to be re-examined or redefined.

Identification of specific research themes related to adaptation and mitigation aspects of forests. Our present state of knowledge on the relationship between climate and plant performance is grossly inadequate for the purpose of modeling future climate change impacts.
Research in the following areas is thus a key prerequisite for coming up with robust adaptation strategies.

1. Ecological research on plant and animal species and communities in relation to climate variability and change: Keeping in view the sensitivity of plant and animal species to climate variability and change, the ecological studies of plant and animal species, plant–animal interactions, and community in relation to climate variability and change are required to be carried out.

2. Dynamic vegetation modeling of climate change impacts on forest ecosystems, biodiversity and adaptation: The few studies so far conducted in India are largely based on equilibrium models, which assume that one forest type is replaced by another forest type under changing climate. The varying climate tolerances of different plant species and the transient phase response of plant species subjected to climate change are not analyzed. There is a need to adapt the existing dynamic vegetation models for application to the diverse tropical forest types in order to analyze the implications of climate change at species level. The ultimate goal is to develop adaptation strategies and practices to reduce vulnerability of forests to climate change. The modeling effort should incorporate adaptation.

3. Impact of climate change on mitigation potential, carbon sinks, and adaptation: India has a large afforestation programme, and it is important to understand the likely impacts of climate change to ensure sustainable management of forests and flow of timber, industrial wood, and non-timber products and conservation of biodiversity. There is a need to analyze the climate impacts using dynamic vegetation models and developing adaptation strategies.

4. Mitigation potential assessment: There is also a need to develop a database on biomass growth rates and soil carbon accumulation rates in forests and plantation systems in different agro-ecological zones of India. This data is required for a realistic assessment of the mitigation potential of the forest sector in India.

Conclusion

It could be seen clearly from the above discussion that climate change has significant impact on forest resources. The protection of forest resources is very essential in the context of climate change. The preservation and conservation of forest resources depends on climate change adaptation and mitigation practices. In order to protect the forest resources from the impact of climate change, many policy adaptation strategies and options have been proposed both by the international organizations and the government of India. The successful implementation of climate change adaptation strategies and options in forest sector depends on involvement and participation of forest department officials, tribal, forest dwellers and other stakeholders of forest resources. The government should encourage the researchers about the development of innovative climate change adaptation options by the way of providing research grants, research support and research infrastructural facilities.

It is significant to note that climate change is a global issue for discussion, there are some gaps and constraints visible in the knowledge of adaptation and mitigation aspect of forestry. Key knowledge gaps include the linkages between impacts of climate change and adaptation and mitigation options. More research is required to better understand climate change challenges and cost-effective solutions at the local levels and to fill knowledge gaps. In order to fill knowledge gaps impacts of climate change and adaptation and mitigation options the following suggestions can be considered.

1. Strengthening the forest area monitoring programme according to forest types at finer spatial resolution
2. Studies to assess and project socio-economic pressures and drivers contributing to forest degradation and loss
3. Field ecological studies to monitor the response of forest vegetation to changing climate at different latitude and altitudinal zones, through long-term permanent research plots
4. Field and laboratory studies to develop plant physiological and phenological characteristics of different forest types as input to climate impact dynamic vegetation models
5. Research programmes to achieve indigenization of input parameters for climate impact models Improvement in regional projections of climate parameters; regional climate modeling
6. Development of transient ecosystem models that deal with multiple stresses: climate change and socio-economic
7. Regional climate model grid level database generation for dynamic vegetation modeling; vegetation characteristics, climate parameters, and socio-economic pressures
8. Studies to identify forest policies and silvicultural practices that contribute to vulnerability of forest ecosystems and plantations
9. Studies to identify forest policies, strategies and silvicultural practices to reduce vulnerability and enhance resilience of forest ecosystems to projected climate change.

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